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Gray-Calhoun and Associates, Inc.
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Greater Hartford Transit District
The Greater New Haven Transit District
Green Way Company
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Institute of Transportation Engineers
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Integrated Technology Solutions, Inc.
Intel Corporation
Intelect Network Technologies
Intelligent Information Incorporated
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Intelligent Transport Systems Australia
Interlink Corporation
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International Fiber Systems, Inc.
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Intertoll (PTY) Ltd.
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ITIS LTD.
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ITS Nevada
ITS New York
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ITS Washington
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ITT Systems & Sciences Corporation
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Kentucky Department of Transportation
Ketron Division of the Bionetics Corporation
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King County Department of Transportation
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Kitsap Transit
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KLD Associates, Inc.
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Korea Road & Transportation Association
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Maricopa County Department of Transportation (MCDOT)
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Metro Networks
Metropolitan Washington Council of Governments
METROPLAN ORLANDO
Metropolitan Area Planning Council
Metropolitan Atlanta Rapid Transit Authority
Metropolitan Transit Authority of Harris County, Texas
Metropolitan Transportation Authority
Metropolitan Transportation Commission (San Francisco Bay Area)
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Miami-Dade Expressway Authority
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Michigan Department of Transportation
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Missouri Department of Transportation
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Motorola Telematics Information Systems
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Piedmont Olsen Hensley, Inc.
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Pioneer Electronics (USA) Inc.
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PULNiX
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Queensland Department of Main Roads
Quixote Corporporation
Raytheon Company Inc.
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Regional Transportation Commission
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RFL Electronics Inc.
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Civil Engineering Department
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Wisconsin Department of Transportation
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XiCAD North America, Inc.
XYPOINT Corporation
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STRATEGIC PLAN FOR

Intelligent Vehicle-Highway Systems

in the United States

Report No: IVHS-AMER-92-3
Prepared by IVHS AMERICA
May 20, 1992

Advanced Traveler Information Systems (ATIS)

Definition

Advanced Traveler Information Systems (ATIS) acquire, analyze, communicate, and present information to assist surface transportation travelers in moving from a starting location (origin) to their desired destination. The systems provide such assistance in a manner that best satisfies the traveler's needs for safety, efficiency, and comfort. The travel may involve a single mode of transportation, or it may link multiple modes together during various parts of the trip.

"ATIS systems acquire, analyze, communicate, and present information."

In this Strategic Plan, ATIS includes only those tasks that provide traveler information. Enhancements related to providing information that aids an operator in safely controlling a vehicle (such as obstacle warning) have been included as part of Advanced Vehicle Control Systems (AVCS) and are described later.

A major component of ATIS is providing information to the driver of a vehicle. Without utilizing any support from outside the vehicle (autonomously), ATIS can employ visual and auditory presentations to inform drivers of their current locations, aid them in planning their routes, help guide them to their desired destinations, and provide various informational services. ATIS may also provide communication between the vehicle and an Advanced Traffic Management System (ATMS) that provides continuous information to the driver regarding traffic conditions, roadway congestion, alternate routes, parking, and other up-to-date information. Real-time information could include locations of accidents, weather and road conditions, optimal routes, recommended speeds, and lane restrictions. ATIS equipment in a vehicle can also be used to provide safety warning information on potentially dangerous driver, vehicle, road, or environmental conditions.

Specific ATIS features and products include the following:

- Navigation systems with electronic vehicle or traveler position determination
- Data communication — transceivers (in-vehicle, home, kiosks, and hand-held) providing information to and receiving information from traffic management centers
- Route planning and guidance systems — multi-modal, single mode, or both — to aid in maximizing travel efficiency

- Automated vehicle identification (AVI) — for uses such as transit vehicle tracking, private vehicle toll debiting, or commercial vehicle credential processing and verification
- Flexible driver interface (variable format video displays and voice output) for providing maps, traffic information, route guidance, road sign information, and other travel information
- Warning systems for various operational and maintenance conditions on a transit, commercial, or private vehicle
- Emergency (Mayday) services with signaling (automated or manual) and response capabilities
- A wide variety of databases, including detailed maps, business directories, transit schedules, tourist information, and the location of various services
- Integrated ATIS/AVCS systems that channel AVCS vehicle control and driver condition information warnings through the ATIS
- Dynamic route guidance that can reroute vehicles around traffic congestion or incidents

Developing and deploying ATIS will be done in the context of a long-term vision so that early installations can evolve gracefully into permanent installations.

There is much overlap between the general functions provided by ATIS and the application of ATIS functions to both public transportation (such as transit schedule information provided at kiosks) and commercial vehicle operations (such as routing). This Strategic Plan has handled the overlap by addressing ATIS features that apply primarily to public transportation or to commercial vehicle operations in those respective sections.

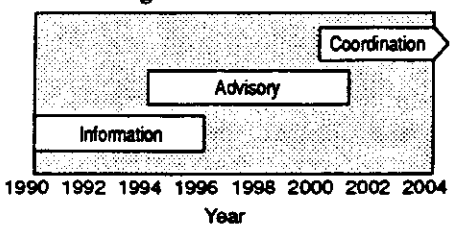
Characteristics and Requirements

The evolution of ATIS is expected to occur in three stages: an information stage (near term), an advisory stage (middle term), and a coordination stage (longer term). Detailed descriptions of the operational features for each stage are provided in the following sections. It should be noted that not all ATIS products will necessarily evolve through all three stages. Some products may initially be deployed as coordination stage products, while other products may mature as information stage products. Since most of the required enabling technologies already exist, advancement through the evolutionary stages is not expected to require major technological breakthroughs. Thus, ATIS development will primarily be an engineering and applications task. However, research, development, and significant operational

testing are required to apply the technologies, define standard interface requirements, quantify benefits, reduce costs, and assure that the systems operate in a safe and efficient manner.

In ATIS systems, it is important that the traveler not be confused by an overload of information. It is particularly important that a driver not be distracted, thus reducing attention to the driving task. The types and amounts of information and the methods of presenting information must be carefully studied in order to ensure that highway safety and traveler efficiency are enhanced and not degraded by information systems. Human factors studies, including cognitive and user demographic analyses, are required to establish the effectiveness and acceptance of any proposed communication or information system.

Development of ATIS in Three Stages



Advances in electronic technology have spurred development of an assortment of communication systems and media which make it easier to provide information. They allow information to be provided either to a driver in a vehicle or to a traveler in the home, for example, using a personal computer. Information such as electronic route maps, tourist guides, and service directories can be self-contained within the vehicle and can be accessed through media such as a compact disc (CD-ROM) or a computer disc. Vehicle status and warning indications can also be provided through self-contained in-vehicle sensors.

On-board display of roadside signs provides both safety and navigation benefits. Such devices replicate warning or navigational roadside signs that may be obscured or may be difficult to read during night driving or inclement weather. They can also display new information when signs need to have their messages changed, such as to lower speed limits during ice, snow, rain, or fog conditions. On-board displays allow messages to be tailored to the needs of specific vehicles, such as heavy trucks.

"Human factors studies are essential for ATIS effectiveness and acceptance."

Although all of these systems add convenience and security to the traveling experience, they lack the dynamic, or real-time, traffic and roadway condition information that is necessary to optimize route selection and other operational decisions. To obtain that information, communication links with ATMS must be established. A one-way link from ATMS to the traveler can provide up-to-date information on traffic congestion, safety advisories, parking lot status, and environmental conditions (such as ice, snow, and rain). A two-way communication link with a vehicle allows the vehicle to serve as a traffic sensor. As such, it can provide information to the traffic management system, allowing the system to anticipate congestion and provide relief measures. A two-way communication link also facilitates traveler interaction with ATMS, allowing specific information to be provided by both the traveler (for example, origin and destination or Mayday signals) and the ATMS (such as specific routing or Mayday acknowledgement).

Current Status

Work on ATIS technology has been under way for several decades. Early work was supported by the Federal Highway Administration's (FHWA) Electronic Route Guidance System (ERGS) program. In the mid-1980's, the California Department of Transportation (CALTRANS) renewed its emphasis on utilizing advanced technology to deal with growing urban traffic congestion. Other government organizations, industries, and universities have since become active in this field. The United States led the world in developing ATIS technologies in the late 1960's and early 1970's, but now lags both Europe and Japan. Recent competitive efforts on ATIS in Japan and Europe are spurring U.S. companies to pursue ATIS technology more aggressively.

"ATIS development has been under way for several decades."

In 1968, FHWA recognized that many drivers cannot effectively use paper road maps, and that growing metropolitan areas contribute to navigation problems. As a result, they sponsored research to develop an ERGS system to provide in-vehicle directional guidance to the driver. If it had been implemented, ERGS would have improved driver navigation in urban areas by providing a series of directional arrows (displayed in the vehicle) to give route guidance between a preselected origin and destination. The proposed system included many of the characteristics that were later implemented in the Ali-Scout System of Berlin and the Autoguide System of London which are currently being planned and piloted. A planned operational experiment in Washington, D.C. was abandoned in 1971 when Congress questioned the timing of the need, the cost, and the technology.

In 1973, the Japanese Comprehensive Automobile Traffic Control System (CACS) project began. By 1979, it had established the feasibility of the ERGS technology. That work established the support for current field operational experiments that are under way in Japan (AMTICS, RACS, and VICS).

As traffic congestion increased in the United States in the 1970's and 1980's, radio transmissions were widely deployed to alert motorists of adverse traffic conditions (traffic advisories through commercial radio stations) and to provide local area guidance to special attractions (highway advisory radio [HAR]). Changeable message highway signs have been implemented on a limited basis to provide speed and warning messages to motorists. Since 1984, mobile communications have been available to the driver through cellular telephones, use of which is expected to climb to 20 to 50 million units by the year 2000.

In-vehicle navigation systems are becoming available that provide information to the driver using both video displays and voice outputs to provide electronic maps, route guidance, and vehicle location. More sophisticated systems will provide real-time information on traffic, road, and weather conditions and will provide route guidance to motorists based on real-time traffic conditions.

A number of technologies are currently available to provide electronic vehicle position determination. Most systems use "dead-reckoning" and "map-matching." Dead-reckoning is a technique that calculates the current location of a vehicle by measuring the distance and direction that the vehicle has traveled since leaving a known starting point. Map-matching minimizes the accumulated error of the dead-reckoned position by comparing the measured path to a map database and making appropriate corrections. The dead-reckoning/map-matching approach can be supplemented by outside information, such as the land-based and satellite-based location and identification systems which are currently in use or are under development. Those systems rely on Global Positioning Satellites (GPS), LORAN-C transmitters, proprietary satellites, or land-based radio and use sophisticated triangulation techniques to determine vehicle locations. Other systems use "spot" beacons to provide the vehicle with a position "fix."

"Use of route planning systems, electronic maps, and in-vehicle signs can improve travel times."

Route planning, improved maps, and more accurate and consistent signs can improve trip navigation and travel times. Pre-trip electronic route planning systems are being developed and are available at certain car rental counters. With those systems, the traveler's origin and destination are entered into a computer and a printout of directions is produced. For trip planning, the systems can estimate minimum time, distance, and travel-related expenditures. Route planning systems can also provide information on locations and schedules for public transportation.

Two broadcasting systems currently used to provide travel information are HAR in the United States and Autofahrer Rundfunk Information (ARI) in Europe. With some systems, drivers are alerted to tune the car radio to a specific frequency, and transmissions are received through the radio. With other systems, special receivers must be installed. Various traffic information broadcasting systems are being considered for use in the United States.

As mentioned earlier in this Strategic Plan, several ATIS operational tests are already planned or under way. Those include Pathfinder in the Smart Corridor of Los Angeles, Travtek in Orlando, and ADVANCE in Chicago.

The Information Stage of ATIS

Definition

During the *information stage*, the primary emphasis will be on providing each traveler with information to improve his or her individual travel planning and decision making. Most capabilities rely on resources contained within a vehicle or a traveler information unit (such as a personal computer or hand-held unit) and are not dependent on any infrastructure. Features falling into this category are transit schedule information units, dead-reckoning and map-matching navigation systems, on-board information databases, and static and dynamic route planning and guidance systems. With limited support from the infrastructure, real-time traffic incident information can be made available to assist travelers in personal route planning.

Characteristics and Requirements

The information stage is the start-up period for ATIS. Many types of systems with diverse features and capabilities will be explored during operational testing. The goal of those studies will be to evaluate the benefits that the various features can provide in real world situations. This stage establishes the technical and socio-political foundations critical to the future of ATIS, including launching the public–private sector alliances that are necessary to make ATIS a reality.

The information stage includes:
- *Navigation*
- *Planning*
- *Guidance*
- *Transit schedules*

An economically viable basic navigation/route guidance and receive-only traffic communications capability will be developed for use in both private and commercial vehicles. Those features form the core capabilities that will eventually reduce congestion and achieve safety benefits. Alternative approaches exist for determining the position of the vehicle. Each of the approaches will be investigated for cost, accuracy, and practicality in a North American system. Minimum requirements for database content will be established and standards developed. Those will encourage map makers and users to gain the mutual confidence necessary to establish a stable market that will become commercially attractive for private enterprise. Necessary human factors and behavioral studies relating to ATIS will begin. The studies will include performance issues, such as color, size, and location of displays, and will also explore the more basic issues of information intelligibility, cognitive performance in driving, and acceptability of various decision-making and routing strategies for both private vehicle and public transit travelers.

On-board route guidance instructions can be communicated to the driver in a variety of ways. In Japan's AMTICS project, the route is indicated as a highlighted overlay on a CRT map display. Auto-Guide (Great Britain) and Ali-Scout (West Germany) both use simplified displays showing schematics of intersections with directional arrows

indicating the next action for the driver to take. All of those systems can be augmented with computer-generated voice, or voice can be used alone without a visual display. As flexible format head-up displays (HUD's) are developed, they will provide another alternative. Extensive human factors research is needed to determine driver reaction to the various approaches.

Alternative approaches also exist for communicating real-time traffic information to the vehicle. They can be as simple as an audio traffic message channel. Approaches that offer the potential for growth into later stages of ATIS include exclusive-channel digital traffic transmitters, digital messages on the sub-carrier of a commercial FM radio station (for example, Europe's Radio Data System's Traffic Message Channel, RDS-TMC), short-range RF or infrared transmitters (beacons) used as electronic signposts, and cellular telephones.

Plan Elements

RESEARCH AND DEVELOPMENT

Systems analysis is required to address overall system design issues, benefits, and trade-offs among the elements that constitute ATIS and its supporting infrastructure. That analysis must deal with the systems on at least three levels: (1) the complete IVHS system design, including technical, societal, and economic issues; (2) the complete ATIS system design, including users, vehicles, and infrastructure; and (3) individual subsystem designs for vehicles, stationary elements, and communication links. The results of those studies need to be corroborated by operational tests and experiments. The IVHS Integration section of this Strategic Plan further addresses R&D for all stages of ATIS, and specific projects are listed in Appendix A.

OPERATIONAL TESTING

Limited operational tests to gather real world experience with information stage ATIS systems are already planned or are under way. It will be necessary to build on that base by conducting additional experiments and operational tests using different approaches to ATIS in various roadway environments and in different sections of the country. The IVHS Integration section of this Strategic Plan further addresses those tests for all stages of ATIS, and specific tests are listed in Appendix B.

DEPLOYMENT

ATIS systems that will begin to be widely deployed during this time include the following:

- Autonomous navigation and route guidance systems that provide vehicle location, mapping, traveler route planning, and route guidance utilizing both visual and audible outputs

- Assisted navigation and route guidance systems that use outside information to provide general traffic condition information
- Automated (electronic) toll collection systems at tollbooths
- Vehicle condition warning systems
- In-vehicle display of road sign information using stored data
- Manual Mayday systems using cellular telephone or other communication means
- Various information systems to assist public transit travelers and features to assist in the efficient operation of commercial fleets (described in the APTS and CVO sections, respectively, for all stages of ATIS)

The Advisory Stage of ATIS

Definition

The advisory stage adds "real-time" information about:
- *Traffic*
- *Transit schedules*
- *Road signs*
- *Weather*

The *advisory stage* will supplement static information with up-to-date ("real-time") traffic information collected and transmitted by the infrastructure. That information will include the amount of time it will take to traverse various parts of the road network (link travel times), road sign information, traffic incident information, weather conditions, and other factors affecting traffic flow. It will also include travel and arrival times for transit systems. The information will be transmitted in a form that can be used by the various systems. The vehicle or traveler unit receives the information and uses it to compute optimum modes and routes. The information that is received will be sorted — only relevant items will be presented to travelers. Once a route is selected, a vehicle system will guide the driver, step-by-step, over the chosen route, providing critical information as needed and automatically modifying the route as road conditions change. Similarly, traveler information units will provide the transit user with real-time schedule information for planning a route, and will then provide guidance during the trip, for example, telling the traveler when and where to get on or off a particular bus in order to meet a connecting train.

Characteristics and Requirements

During the advisory stage of ATIS, the in-vehicle system will begin to do more than just inform the driver of conditions. Using knowledge from the infrastructure, it will also begin to advise the driver of the best course of action to take considering the current conditions. The advice must be credible and must be perceived as both accurate and advantageous, or it will be ignored. Thus, the accuracy of the

navigation system, the route planning information, and the real-time traffic information become extremely critical during this stage.

A major goal of the advisory stage is to provide automated route selection and guidance using up-to-the-minute traffic information. The selection can be based on one or more of a variety of user-selectable criteria such as minimum time, minimum distance, or avoiding freeways. To accomplish this, it is required that traffic information centers acquire traffic data from a wide variety of sources and estimate current and near-future driving time information for all major links in the road network. The estimated link travel times must be periodically transmitted to the traveler information systems, which will use them to select the suggested routes. Additional approaches exist for real-time route selection and guidance. An alternative approach would be to have the route selection done on-board the vehicle using static information while incorporating real-time alternate route information that the traffic information center is transmitting regarding congested areas.

During this stage, ATIS will also provide on-board display of road signs. Those will include both permanent and temporary signs for freeway information, traffic control, and speed limits. The goal is to have the sign information available when the driver needs it, not just when the physical sign is visible. Traffic sign information could be carried in an on-board database, which would be updated by the traffic information transmitters, or the information could be communicated directly to the vehicle from the signs themselves. That could be done in a passive mode (optical reading of sign text by the vehicle) or in a cooperative mode (such as magnetic encoding in the roadway or short-range transmitters on the signs).

Plan Elements

RESEARCH AND DEVELOPMENT

Much of the systems analysis and human factors research described for the information stage of ATIS will continue during the advisory stage. The emphasis will gradually move toward decision-making and dealing with rapidly changing dynamic information. Systems analysis will address traffic data acquisition, data fusion, traffic network balancing issues, and vehicle-to-infrastructure communications.

OPERATIONAL TESTING

The operational tests during the advisory stage will build on those conducted during the information stage. The infrastructure already developed should evolve in concert with the development of new features, which systems will incorporate.

DEPLOYMENT

ATIS systems that are expected to begin to be widely deployed during this time include the following:

- Assisted navigation and route guidance systems that use outside communication to provide routing based on current traffic conditions and to facilitate improved vehicle position tracking
- Automated (electronic) toll collection at highway speeds
- Improved visual and audible user interfaces
- Real-time, changeable message road sign display systems
- Semi-automated Mayday systems
- Systems that provide the driver with AVCS warnings

The Coordination Stage of ATIS

Definition

In the *coordination stage*, the vehicles and the infrastructure will automatically exchange information to optimize the flow and safety of traffic over the entire network. Vehicles will report frequently on their intended destinations and on the traffic conditions encountered along the way. The infrastructure will combine that information with information obtained from all other sources and will be able to predict near-future traffic conditions. The information will be used to provide coordinated routing, traffic signal control, and transit dispatching. Individual vehicles requiring emergency assistance (such as from police or medical personnel or for vehicle mechanical trouble) can either manually or automatically summon the required services. Those services will then be automatically routed to the scene.

Characteristics and Requirements

"The coordination stage features vehicles reporting to the infrastructure."

During the coordination stage, the traffic information center of the previous stages will evolve into a more comprehensive Traffic Management Center (TMC), with responsibility for optimizing traffic flow throughout the network. Private, commercial, and transit vehicles will serve as traffic probes by automatically reporting to the TMC on the traffic conditions and link times they encounter as they travel through the network. Route selection by individual vehicles, using information supplied by the TMC, will account not only for current traffic conditions, but also for predicted traffic conditions based on the routes of other vehicles in the network. Traffic controls will be coordinated with vehicle routing to ensure the maximum effective capacity of the traffic network.

Coordinated route planning can now be accomplished because the TMC can perform route selection and can then transmit routes to individual vehicles or groups of vehicles. That can be done on a way-

point basis — as a vehicle passes one way-point, an optimal route is provided from that way-point to the next way-point in the direction of the destination.

At this stage, the travelers' equipment and the infrastructure will be capable of supporting (without significant additional equipment) an automated emergency (Mayday) service feature. That feature will provide the capability to summon emergency assistance and provide vehicle location. It can be initiated either by the traveler or automatically, as in the case of an accident. The Mayday feature could automatically dial (for example, on a cellular telephone or over a satellite communication link) directly to a service provider that is equipped to deal with such digital messages.

Plan Elements

RESEARCH AND DEVELOPMENT

The coordination stage of ATIS requires additional systems analysis, including the following:

- Division of tasks between traffic management centers and vehicles
- Development of more capable software for traffic control, including multi-modal data fusion and routing
- Defining vehicle-to-vehicle communication system requirements

OPERATIONAL TESTING

Operational tests for this stage of ATIS will enable full-scale implementation of specific ATIS features which, in earlier stages, have proven to be beneficial and cost-effective.

DEPLOYMENT

ATIS systems that may begin to be widely deployed during this time include the following:

- Route guidance systems that interact cooperatively with a traffic management center, providing the center with information, as well as receiving information
- Fully automated Mayday signaling and coordinated service dispatching